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Research article

A sectoral-level analysis of the short- and long-term impacts of the COVID-19 pandemic on China's stock market volatility

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HIGHLIGHTS

- COVID-19-related new cases, new deaths, and cumulative cured cases were associated with higher stock market volatility.
- COVID-19's impacts varied across different sectors.
- COVID-19 events increased volatility continuously for up to 6 days.
- COVID-19 daily deaths impacted volatility more than confirmed and cured cases.
- In the long run, the fundamental aspects of the company and investors' behaviour also made great sense.

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ABSTRACT

Sampling China's Shenyin & Wanguo Sectoral Indices for 28 industries and 3272 listed firms included in those indices, and using industry- and firm-level daily data up to December 31, 2020, this paper empirically examined the short- and long-run impacts of the COVID-19 pandemic on stock return volatility. The results of the event study and univariate graphic analysis suggested that the market volatilities of the 28 industries were affected by COVID-19 events at various levels and that the events increased the volatility continuously for up to 6 days. The results of the panel data regression models revealed that the COVID-19-related daily new confirmed cases, daily new deaths, and cumulative cured cases were associated with higher volatility for all industries, although the impact levels were small; the daily deaths impacted volatility more than confirmed and cured cases. Finally, positive and significant effects of firm-specific variables such as total assets, turnover ratio and trading volume were recorded, indicating that fundamental aspects of the company and investors' behaviour also made great sense.

1. Introduction

Declared by the World Health Organization (WHO) as a global pandemic, as of June 10, 2022, the 2019 novel coronavirus (COVID-19) has spread to over 200 countries and regions, infecting over 532 million people, resulting in more than 6.30 million deaths globally and inflicting damage on human lives and the world economy. The pneumonia outbreak and its intertwined health, social and economic impacts have wreaked havoc on investors' emotions and market sentiment, leading to tumbles of major markets worldwide (Ali et al., 2020; Baker et al., 2020; Baek et al., 2020; Zhang et al., 2020; Li et al., 2021; Pandey and Kumari, 2020).

In this context, sampling China's Shenyin & Wanguo Sectoral Indices (SWSI) for 28 industries and 3272 listed firms included in those indices, and using data up to December 31, 2020, this study conducts an industry-level analysis of the short- and long-run impacts of the outbreak and spread of COVID-19 on China's stock market volatility. Our interest is to find whether there is systematic evidence that COVID-19 pandemic induces stock market volatility and whether different industries react to COVID-19 in a similar fashion or whether the responses vary by industry. We employ two complementary methodologies to explore the data: event study and univariate graphic techniques in the short-run analysis and panel data fixed/random effect models in the long-run analysis separately.

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Table 1. List of sample events.

Event	Date	News information
A	Dec 31, 2019	27 confirmed cases of viral pneumonia were reported in Wuhan City, Hubei Province and the WHO was informed of the occurrences of viral flu-like symptoms.
B	Jan 11, 2020	The first death from novel coronavirus was reported.
C	Jan 20, 2020	The Academician Nanshan Zhong, who heads China's COVID-19 Expert Team and the High-level Expert Group of the NHC, made it clear in an interview that there was a phenomenon of human-to-human transmission for the novel coronavirus.
D	Feb 3, 2020	On January 31, the WHO declared the novel coronavirus outbreak a "public health emergency of international concern". Since the stock markets in China did not operate from January 24 to February 2 due to the Spring Festival, the event day is shifted to February 3.
E	Feb 12, 2020	An improvement in the diagnosis led to a better detection of confirmed cases, with the reported number surging to 15,152.
F	Mar 12, 2020	The WHO declared the novel coronavirus outbreak a global pandemic.
G	Apr 17, 2020	For verification, the health authorities in Wuhan revised the confirmed and death tolls, adding 325 more infections and 1290 more fatalities
H	May 11, 2020	Jilin Province adjusted the coronavirus risk level in Shulan City from medium to high on May 10 after a COVID-19 cluster infection, making it the only such area in China with that categorization. Since the stock markets in China do not operate on weekends, the event day is shifted to May 11.
I	Jun 12, 2020	Beijing Centre for Disease Control and Prevention reported the first new local case at a regular press conference on June 11 (4:00 p.m.), before which Beijing reported zero local transmissions for 56 days. Since the stock markets in China do not operate after 3:00 p.m., the event day is shifted to June 12.
J	Jul 17, 2020	NHC reported on July 17 that a new locally transmitted COVID-19 case was confirmed in Urumqi, capital of the Xinjiang Uygur Autonomous Region on July 16, after 147 days of zero local transmissions in Xinjiang and the city has applied lockdown measures in its residential communities and villages since July 17.
K	Jul 30, 2020	NHC reported on July 30 that the re-emergent new confirmed locally transmitted cases surpassed 100 on July 29.
L	Sep 25, 2020	After nearly 2-month period without local transmission of COVID-19 cases in mainland China, Qingdao City in Shandong Province reported on September 25 that two port workers were detected as having asymptomatic COVID-19 infection during routine screening. Live new coronavirus was detected and isolated from positive samples from contaminated outer packages of imported frozen cod.
M	Oct 12, 2020	On October 11, Qingdao reported three asymptotic cases related to Qingdao Chest Hospital, a facility designated for treating people with imported cases of COVID-19. The above-mentioned two port workers had been sent to this hospital for further investigation and treatment. Since October 11 was Sunday, the event day is shifted to October 12.
N	Oct 26, 2020	On October 25, the Information Office of Xinjiang Uygur Autonomous Region held a news conference and reported 137 new asymptomatic carriers in Kashgar Region. Four towns were rated as high-risk. Since October 25 was Sunday, the event day is shifted to October 26.
O	Nov 9, 2020	Tianjin Health Commission reported on November 9 that two workers were found positive via nucleic acid test on November 8 and 9, respectively. Both of them were related to cold imported food. Three areas were rated as medium risk.
P	Nov 23, 2020	On November 21, Inner Mongolia Autonomous Region reported 2 new locally transmitted confirmed cases in Manzhouli, a border city under the jurisdiction of Hulunbuir. Since November 21 was Saturday, the event day is shifted to November 23.
Q	Dec 11, 2020	Heilongjiang Health Commission reported on December 11 that on December 10 two new domestic confirmed cases were detected in Dongning County under Mudanjiang City, both of which launched their Level III emergency response.

In this study, we specifically focus on stock market volatility because as a barometer of financial risk or uncertainty, volatility is paramount to stock market operation (Zaremba et al., 2020). The extreme uncertainty associated with the ongoing pandemic may translate into unprecedented volatility and a possible threat to financial stability (Baker et al., 2020). Therefore, illustrating the drivers of stock market volatility in 2020 provides a preview of the future economic impacts of COVID-19 (Ramelli and Wagner, 2020) and can help formulate policies to address the financial fluctuations caused by infectious diseases that may reoccur in the future.

We adopt China as a case for several reasons. First, the spread of COVID-19 in China has been very astounding. In 2020, mainland China reported a total of 87,071 confirmed cases, including 82,067 recoveries and 4634 deaths. After the occasional and small outbreaks in 2021, China was hit again by a new wave of coronavirus outbreaks in the spring of 2022, which was sparked by the more contagious Omicron variant. Second, the stock market is naturally vulnerable in times of economic downturns. The COVID-19 outbreak has caused a plunge in China's GDP growth—as it expanded 2.3% year-on-year in 2020, which has been the lowest point over the last decade. The stock market in China inevitably experienced strong volatilities. Finally, research on the impacts of COVID-19 on China's stock market emphasized abnormal stock returns (Al-Awadhi et al., 2020; Li et al., 2021; Liew and Pauh, 2021; Sun et al., 2021; Wu et al., 2021) instead of volatility.

This study reports four findings. First, the COVID-19 pandemic contributed to China's stock market volatility, in the short run and in the long run, and the impact levels of COVID-19 shocks varied across different sectors. Second, in the short run, the COVID-19-related events increased market volatility continuously for up to 6 days. Third, in the long run, the COVID-19-related daily new confirmed cases, daily new deaths, and cumulative cured cases were associated with higher stock market volatility, although the impact levels were small; the daily deaths impacted volatility more than confirmed and cured cases. Fourth, the positive and significant effects of firm-specific variables of total assets, turnover ratio and trading volume were recorded, indicating that fundamental aspects of the company and investors' behaviour also made great sense.

Table 2. Summary statistics of key variables in the full sample.

	Obs.	Mean	Std. Dev.	Min	Max
Volatility	795,096	0.0009	0.0019	7.89E-10	0.6935
New Cases	795,096	233.4776	1109.078	0	141,09
New Deaths	795,096	8.8025	26.5771	0	146
Total Cured	795,095	67,750.53	25,862.91	0	82,067
Total Assets	795,096	15.7619	1.1857	9.8485	21.6435
M/B Ratio	795,096	3.6791	6.4594	0.1133	342.6934
Turnover Ratio	795,096	0.0282	0.0374	0	0.7594
Trading Volume	795,096	1.76E+07	3.80E+07	100	2.43E+09

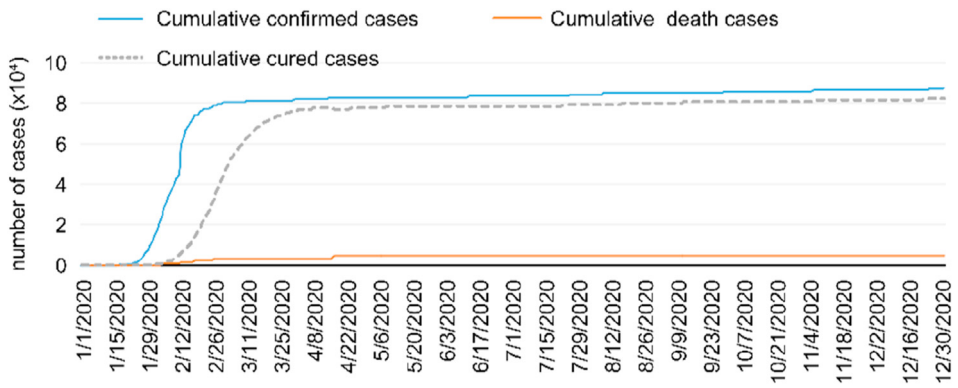

Figure 1. Time series plots of the number of COVID-19 cases in mainland China. Note. Data are from NHC and WMHC. On April 17, 2020, for verification, the health authorities in Wuhan revised the confirmed and death tolls, adding 325 more infections and 1290 more fatalities; the number of cumulative cured cases was reduced to 925.

The contribution of this study is fourfold. First, in the context of China, we conduct a sectorial analysis to examine the short-run and long-run stock market's volatility responses to COVID-19 by using industry- and firm-level daily data respectively. Second, we resort to event study and univariate graphic techniques inspired by Eichengreen et al. (1995), Frankel and Rose (1996), Kaminsky and Reinhart (1999), and Gourinchas and Obstfeld (2012) rather than the conventional event study method focusing on a single event to investigate the reactions of China's industries to a series of sudden COVID-related news announcements—we used the term *event* to denote the news announcement. Third, we employ a panel regression approach with a relatively long data period and sufficient time-series observations, which produces robust estimations and high statistical inference, to capture the long-term association between COVID-19 and stock market volatility. Fourth, in the panel regression analysis, except for the commonly used *negative news* of confirmed cases and deaths, we examine the impact of *positive news* of recoveries.

The rest of this paper proceeds as follows. Section 2 reviews the literature. Section 3 describes the methodology. Section 4 reports data-related information, including data collection, descriptive analysis of regression variables, and pandemic and indices volatility movements graphs. Section 5 reports the empirical results. And Section 6 gives a brief conclusion.

2. Literature review

The efficient market hypothesis (EMH) asserts that asset price fully reflects all available and relevant information (Choi, 2021). According to the EMH, the performance of a stock market, can be significantly affected by some new information or events such as natural disaster, terrorist attacks, financial crisis, and political events (Chan, 2003; Zach, 2003; Ramiah, 2013; Al-Awadhi et al., 2020; Izzeldin et al., 2021), as the uncertainties and risks along with the information or the events may cause anxiety, panic, fear and sentiment among investors which will impact investors' investment decisions and the stock market volatility (Baek et al., 2020; Pandey and Kumari, 2020). The literature has outlined the resulted impacts from COVID-19 outbreak in three main channels. These channels consist of (1) the consistent influx of COVID-19-related news that can cause negative sentiment and panic among investors and lead to news-implied volatility (Baek et al., 2020; Zaremba et al., 2020), (2) some of the government's non-pharmaceutical interventions accompanying the severe pandemic crisis that may cause sizable economic and social costs, including sharp contraction in economic activities, rising unemployment, firm closures, decline in wealth and loss of income (Zaremba et al., 2021) which will destabilize the stock market, and (3) the huge unpredictability of the ongoing COVID-19 pandemic that may well lead to enormous market uncertainty, result in subsequent "flight to safety" (Baele et al., 2020), increase trading activity and contribute to volatility.

Some notable studies have documented the impacts of COVID-19 on stock market volatility. Baker et al. (2020) carried out a textual analysis and asserted that no previous infectious diseases have influenced US stock market volatility as powerfully as COVID-19 did. Barro et al. (2020) reached similar conclusion that given the enormous potential costs in lives and economic activity, the impact of COVID-19 on stock markets was unique in comparison to previous pandemic outbreaks. Adopting different proxies of COVID-19, such as infection cases and deaths, some attempts showed that COVID-19 has significantly triggered stock market volatility across various economic settings, worldwide (Ali et al., 2020; Zhang et al., 2020; Kusumahadi and Permana, 2021; Sergi et al., 2021) or within a country (Onali, 2020; Albulescu, 2021; Baek and Lee, 2021; Baig et al., 2021; Hoshikawa and Yoshimi, 2021; Xu, 2022).

The aforementioned studies conducted aggregated index analysis assuming homogeneity in stock volatility. However, the effects of COVID-19 may vary across industries, depending on the type of business (Choi, 2021) and the extent of a sector's exposure to COVID-19 (Baek et al., 2020). Examining aggregate markets may include bias and hide useful information about the behaviour of individual industries (Choi, 2021). Regarding this aspect, several contributions are worth mentioning. Using the world benchmark indices data from January 2020 until April 2020 and adopting the ordinary least square (OLS) regression method, Haroon and Rizvi (2020) unveiled that COVID-19-related negative sentiment and panic significantly increased volatilities of indices in world markets, while a high volume of COVID-19-related news (media coverage) was associated with lower volatility. Their analysis of 23 US sectoral indices suggested that volatilities in indices of most industrial sectors were positively affected by panic-causing news. However, the extent of media coverage and news sentiment was not associated with the price volatilities of the majority of industries. This finding is somewhat counterintuitive and raises concerns about the statistical power of their relatively short sample period, because the constant flow of COVID-related news may lead to news-implied volatility (Zaremba et al., 2020). The news sentiment can stimulate trade activities, and then influence volatility as well as volume (Zhang et al., 2016; Broadstock and Zhang, 2019; Ali et al., 2020; Audrino et al., 2020). In addition, Haroon and Rizvi (2020) found that the panic and media coverage indices were related to confirmed cases but not to deaths. In another study utilizing indices of 30 US industries for the same period as Haroon and Rizvi (2020) and using panel regression approach, Baek et al. (2020) documented an industry-wide variance in volatility reactions to COVID-related deaths and recoveries, which exhibited a positive–negative asymmetry. Based on daily estimation of simple epidemiological models of infectious disease, Alfaro et al. (2020) found an inverse relationship between real time changes in predicted infections and US industry- and firm-level stock returns. Adopting a smooth transition heterogeneous autoregressive model (ST-HAR) with data from stock markets and 10 business sectors of the G7 economies, Izzeldin et al. (2021) revealed that different industries

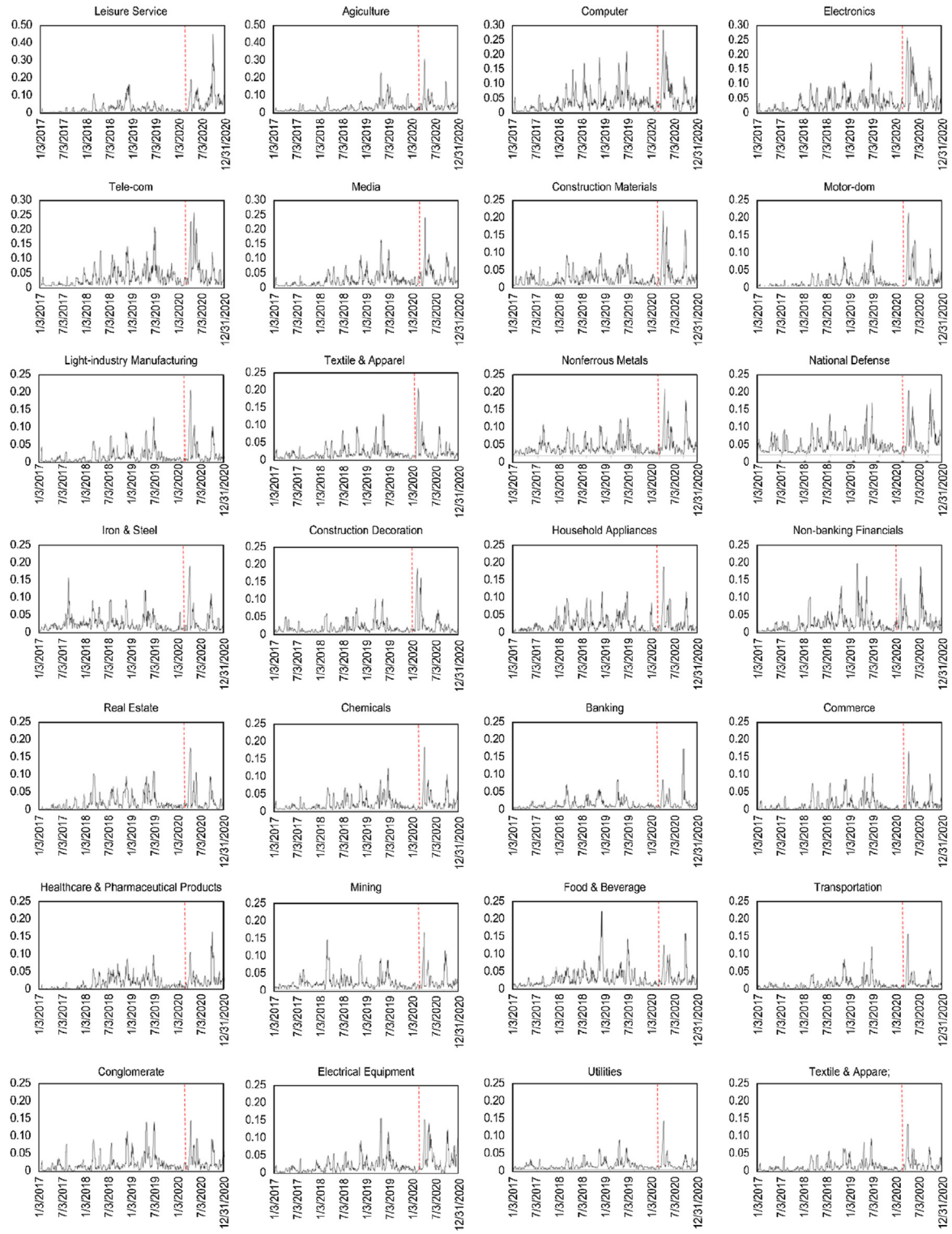

Figure 2. Time series plots of volatilities of the sectoral indices. Note. The dotted vertical line denotes January 3, 2021.

were impacted by COVID-19 at different levels. Focusing on Chinese-listed tourism stocks and using an event study method, Wu et al. (2021) showed that the COVID-19 outbreak negatively impacted the tourism sector stock returns. Employing a sample of 5432 listed non-financial firms of 6 sectors across 10 most impacted countries in the European Union and using a stress testing approach, Rizvi et al. (2022) assessed the impact of COVID-19 pandemic on firms' valuations, and highlighted a significant loss in valuations across all sectors due to a possible reduction in sales and an increase in equity costs.

Event analysis has been used to measure the short-term influence of COVID-19 on the stock market (Goodell and Huynh, 2020; Liu et al., 2021; Pandey and Kumari, 2020; Sun et al., 2021; Wu et al., 2021). The conventional event study method usually focuses on a single COVID-19-related event. However, the spread of COVID-19 evolves over a matter of days and is not a one point of time event (Ashraf, 2020). Although COVID-19-related events share certain common features, no two events are the same. Due to differences in the risk profiles of events, investors may react differently (Sharif et al., 2020). In the spirit of

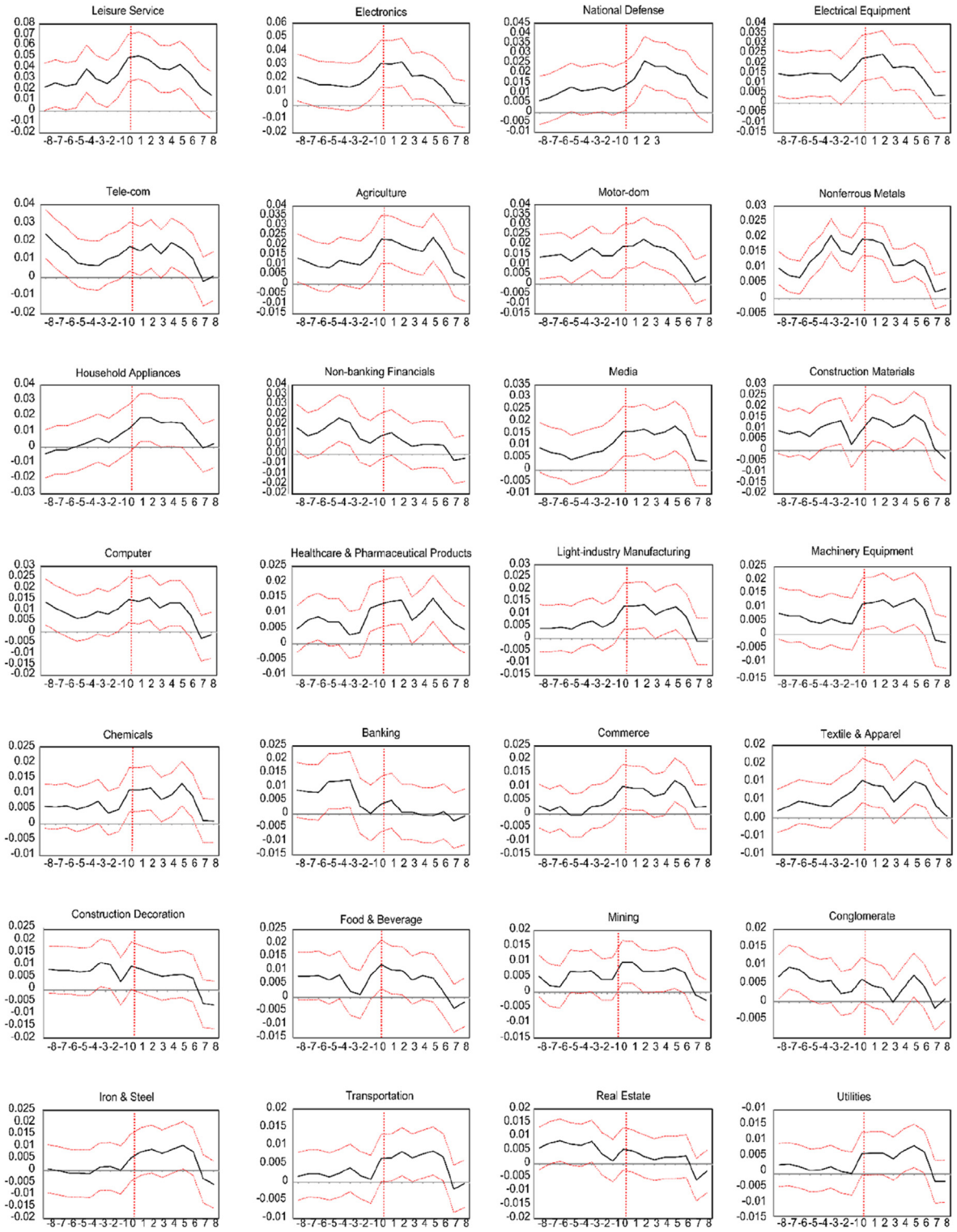

Figure 3. Empirical regularities around the COVID-19-related event.

Eichengreen et al. (1995), Frankel and Rose (1996), Kaminsky and Reinhart (1999), and Gourinchas and Obstfeld (2012), we employ event study and univariate graphic analysis approach to identify the average effects of a series of COVID-19-related events on China's stock market volatility. Little research resorted to such an analysis to capture the effects of COVID-19 events. To the best of our knowledge, there is only one recent Chinese article authored by Fang et al. (2020) to which our analysis is comparable in spirit. Fang et al. (2020) analysed the cumulative consequence of 5 COVID-19-related events on the volatility of China's CSI 300 Index in the period between January and April 2020. Besides the relatively short sample period and rather small size of events, a potential drawback of Fang et al. (2020) was that they implicitly allowed for interaction effects since in their analysis joint events (such as good news and bad news) happened in exactly the same day, or the *post-event* phases of two neighbouring events overlapped. Nevertheless, they did not consider the interaction effects of the twin events relative to

Table 3. Results for Fisher-ADF panel unit root tests.

Variable	Statistic (P)	p-value
Volatility	6.88E-04	0.0000
New Cases	2.00E-05	0.0000
New Deaths	2.96E-04	0.0000
Total Cured	1.41E-05	0.0000
Total Assets	2.51E-04	0.0000
M/B Ratio	2.58E-04	0.0000
Turnover Ratio	1.25E-05	0.0000
Trading Volume	1.28E-05	0.0000

an isolated event. Moreover, they performed aggregated index analysis rather than industry-level analysis. In contrast, our sectoral-level analysis focuses on the period spanning one year of COVID-19 history to study a comprehensive set of COVID-19 events and the selection of the events enables us to avoid the possible interaction effects between two events.

Since the spread of COVID-19 evolves over time and its effect is not temporary, we further employ a panel estimation approach to examine the impact of COVID-19-related daily new confirmed cases and deaths and cumulative cured cases on stock market volatility to uncover the long-term relationship between COVID-19 and volatility for China's stock market.

3. Methodology

Adopting similar definitions to Baek et al. (2020), Baek and Lee (2021), and Engelhardt et al. (2021), we consider volatility as the standard deviation of daily index/stock returns on the 7-day moving window. The daily index/stock return is $r_{it} = \ln S_{it} - \ln S_{it-1}$, where S_{it} is the index value of sector i or the price of stock i at trading day t. The volatility is calculated as:

$$\sigma it = \sqrt{\frac{1}{N-1}\sum_{t=1}^{N}(r_{it} - \bar{r}_i)} \quad (1)$$

where $N = 7$, and $\bar{r}$ is the mean value of r_{it}.

We first use the event study and univariate graphic analysis to estimate the effects of COVID-19 events on index volatility. We start by compiling a list of COVID-19 events. We use the white paper on *Fighting Covid-19: China in Action*, which was released by the State Council Information Office of the People's Republic of China in June 2020, and the daily Report of Epidemic Situation and irregularly scheduled Prevention and Control Dynamics provided by National Health Commission of China (NHC), or provincial or municipal Health Commission, to compile a total of 17 major officially declared COVID-19 events in the period from December 31, 2019 to December 31, 2020. We tabulate and categorize the events in Table 1.

To address the objective of this study, that is, testing whether COVID-related events affect stock return volatility, we consider a variable $Volatility_{ij}$, where i refers to the index of sector i and j to the period. The approach is to estimate the expectation of $Volatility_{ij}$ as a function of the temporal distance from a series of COVID-19 events. The following specification is postulated:

$$Volatility_{ij} = \alpha_i + \sum_{S=-8}^{8} \beta_{sj}\delta_{sj} + \varepsilon ij \quad (2)$$

The dummy variable $\delta sj = 1$, when the index of sector i is s days away from the COVID-19 event in period j, i.e., $\delta_{sj} = \begin{cases} 1, & t = t_{j0} + s \\ 0 \end{cases}$. t_{j0} denotes the event day. When the event day is not a trading day, it will be shifted to the following trading day. The event window is$[-8,8]$ and $s \in [-8, 8]$, including the *pre-event* phase in the 8 trading days preceding an event, the event date (s = 0), and the *post-event* phase lasting 8 trading days. α_i measures industry fixed effects, and ε_{ij} is the error term. The coefficients β_{js} are our primary parameters of interest and they measure the cross section average effect of a series of COVID-19 events on index volatility in the corresponding days over the COVID-event window.

Following Eichengreen et al. (1995) and Frankel and Rose (1996), we exclude events which occurred within eight days of each other to avoid double-counting the events. That is, if one COVID-19 event occurs on day t, another chosen event occurs at least 8 days later.

We conduct OLS regression to calculate $\beta_{-8}, \beta_{-7} \ldots\ldots \beta_{-1}, \beta_0, \beta_{+1} \ldots\ldots \beta_{+7}, \beta_{+8}$ which can capture the average effect of the 17 COVID-19 events on index volatility before, during and after the events. The "event study" analysis is intrinsically univariate (Frankel and Rose, 1996) and does not always allow us to assess statistical significance with confidence (Gourinchas and Obstfeld, 2012). More systematical exploration of the time varying relationship between COVID-19 variables and other independent variables can be provided by regression work. We next conduct the panel regression analysis. The specification is:

$$Volatility_{it} = \alpha_0 + \alpha_1 * COVID - 19_{t-1} + \beta * CONTROL_{it} + \varepsilon_{i,t} \quad (3)$$

$Volatility_{it}$ is the return volatility of stock i and it is regressed on $COVID - 19_{t-1}$ — the lagged values of the numbers of daily new confirmed cases (*new cases*) and deaths (*new deaths*) and cumulative cured cases (*total cured*). $CONTROL_{it}$ is a set of firm-specific variables created following previous studies—total assets (Sun et al., 2021), market-to-book ratio (Al-Awadhi et al., 2020), turnover ratio (Zaremba et al., 2021) and trading volume (Onali, 2020). α_0 and $\varepsilon_{i,t}$ are the constant and error terms, respectively.

4. Data

4.1. Data collection

The SWSI used in this study was issued by Shenyin & Wanguo Securities (SWS) Research Co., Ltd under the SWS industry classification standard 2014 and it consists of all the firms listed on the China A-share market. In this way, the SWSI sectors serve as a classification criterion for the entire China A-share market. The 28 component indices of SWSI represent agriculture, banking, chemicals, commerce, computer, conglomerate, construction decoration, construction materials, electrical equipment, electronics, food and beverage, health care and pharmaceutical products, household appliances, iron and steel, leisure service, light-industry manufacturing, machinery equipment, media, mining, motordom, national defence, nonbanking financials, nonferrous metals, real estate, tele-com, textile and apparel, transportation, and utilities.

We exclude firms with missing data and special treatment (ST) or particular transfer (PT) because of risks in abnormal finance or other conditions. The final sample contains 3272 firms. We collect daily data on the SWSI index value from January 3, 2017 to December 31, 2020 to compare the index value volatility before and during COVID-19 and to conduct the event study and univariate graphic analysis. We also collect daily data on stock returns and COVID-19- and firm-specific variables from January 1, 2020 to December 31, 2020 to conduct the panel regression analysis. The reasons for choosing the end of December 2020 as the end of sample period are summarized as follows. At the core of our dataset are COVID-19 variables, the 28 component indices of SWSI, and the 3272 firms included in SWSI and classified as members of each of the specific sectors. Against the backdrop that the financial markets around the world are becoming increasingly interconnected, the SWS Research has built a new industry classification system covering China A-shares and the firms included in "Shanghai and Hong Kong Stock Connect" programme and "Shenzhen and Hong Kong Stock Connect" programme, that is, SWS industry classification standard 2021. The new industry classification results have been updated since July 31, 2021. The new SWSI based on the SWS industry classification standard 2021 was released on December 13, 2021, and the old SWSI based on the 2014

Table 4. Regression results.

	Full sample	Agriculture	Banking	Chemicals	Commerce	Computer	Conglomerate	Construction Decoration
New Cases	5.74E-08***	7.19E-08***	2.50E-08***	6.42E-08***	5.30E-08***	4.93E-08***	4.68E-08**	4.34E-08***
	(2.53E-09)	(1.40E-08)	(5.11E-09)	(7.66E-09)	(8.46E-09)	(1.15E-08)	(2.19E-08)	(8.50E-09)
New Deaths	3.27E-06***	5.10E-06***	1.66E-06***	4.00E-06***	3.29E-06***	5.39E-06***	2.80E-06**	4.20E-06***
	(1.21E-07)	(6.67E-07)	(2.44E-07)	(3.66E-07)	(4.05E-07)	(5.50E-07)	(1.05E-06)	(4.06E-07)
Total Cured	1.14E-09***	8.06E-10	1.06E-09***	2.08E-09***	8.37E-10**	2.84E-09***	1.79E-09*	1.49E-09***
	(9.93E-11)	(5.50E-10)	(2.11E-10)	(3.02E-10)	(3.30E-10)	(4.52E-10)	(8.48E-10)	(3.30E-10)
Total Assets	0.00044***	5.70E-05**	0.00079***	0.00033***	0.00055***	6.03E-05**	1.46E-05	0.00068***
	(1.60E-05)	(2.88E-05)	(0.00014)	(5.94E-05)	(6.79E-05)	(2.65E-05)	(4.42E-05)	(6.96E-05)
M/B Ratio	-1.41E-06	2.77E-05***	-0.00048***	-1.08E-05	-6.89E-05***	1.43E-05***	2.13E-05	1.75E-05
	(1.90E-06)	(4.91E-06)	(0.00013)	(1.07E-05)	(2.05E-05)	(4.07E-06)	(1.58E-05)	(1.21E-05)
Turnover ratio	0.0142***	0.01206***	0.00708***	0.01347***	0.01785***	0.01492***	0.01163***	0.01165***
	(7.70E-05)	(0.00045)	(0.00022)	(0.00021)	(0.00047)	(0.00031)	(0.00061)	(0.00029)
Trading Volume	3.54E-12***	2.06E-12***	1.88E-12***	4.61E-12***	4.58E-12***	3.36E-12***	2.86E-12***	6.83E-12***
	(9.18E-14)	(5.54E-13)	(8.67E-14)	(3.19E-13)	(3.67E-13)	(5.55E-13)	(7.71E-13)	(3.21E-13)
– cons	-0.00668***	-0.00068	-0.01400***	-0.00491***	-0.00819***	-0.00082**	-6.20E-05	-0.01048***
	(0.00025)	(0.00045)	(0.00250)	(0.00089)	(0.00101)	(0.00041)	(0.00066)	(0.00106)
Obs.	795,096	17,496	8505	71,199	18,225	53,031	6318	25,272
	Construction Materials	Electrical Equipment	Electronics	Food & Beverage	Health Care & Pharmaceutical Products	Household Appliances	Iron & Steel	Leisure Service
New Cases	5.07E-08***	4.20E-08***	6.87E-08***	5.22E-08***	9.49E-08***	5.18E-08***	3.52E-08	6.00E-08***
	(1.40E-08)	(9.38E-09)	(1.03E-08)	(1.44E-08)	(1.47E-08)	(1.55E-08)	(6.22E-08)	(2.04E-08)
New Deaths	2.70E-06***	3.66E-06***	2.44E-06***	2.91E-06***	2.28E-06***	3.60E-06***	-3.91E-06	3.56E-06***
	(6.69E-07)	(4.47E-07)	(4.92E-07)	(6.91E-07)	(7.02E-07)	(7.37E-07)	(2.97E-06)	(9.66E-07)
Total Cured	3.07E-10	1.68E-09	2.61E-09***	1.55E-09**	1.63E-10	1.38E-09**	-7.45E-09***	1.34E-09*
	(5.51E-10)	(3.74E-10)	(4.07E-10)	(5.96E-10)	(6.00E-10)	(6.08E-10)	(2.46E-09)	(7.78E-10)
Total Assets	3.21E-06	0.00038***	0.00019***	0.00104***	0.00039***	0.00086***	-0.00052	9.23E-05***
	(3.60E-05)	(6.70E-05)	(7.25E-05)	(9.31E-05)	(9.71E-05)	(0.00015)	(0.00081)	(3.35E-05)
M/B Ratio	4.62E-05***	1.54E-05	-6.65E-06	-7.07E-05***	1.57E-05	-6.25E-05**	1.50E-05	2.40E-07
	(8.83E-06)	(1.01E-05)	(7.53E-06)	(8.76E-06)	(9.73E-06)	(3.14E-05)	(0.00034)	(9.26E-07)
Turnover ratio	0.01624***	0.01655***	0.01389***	0.01044***	0.01315***	0.01461***	0.04523***	0.00726***
	(0.00068)	(0.00027)	(0.00025)	(0.00056)	(0.00047)	(0.00065)	(0.00434)	(0.00151)
Trading Volume	7.00E-12***	7.08E-12***	1.49E-12***	1.10E-11***	7.31E-12***	6.23E-12***	-9.66E-13	3.05E-11***
	(1.02E-12)	(3.14E-13)	(2.41E-13)	(1.27E-12)	(9.32E-13)	(7.08E-13)	(1.18E-12)	(3.28E-12)
– cons	4.71E-05	-0.00576***	-0.00268***	-0.01637***	-0.00601***	-0.01289***	0.00902	-0.00121
	(0.00055)	(0.00102)	(0.00112)	(0.00147)	(0.00151)	(0.00223)	0.01287	(0.00051)
Obs.	15,552	40,338	55,647	20,898	70,956	12,879	7533	7776
	Light-industry Manufacturing	Machinery Equipment	Media	Mining	Motor-dom	National Defense	Nonbanking Financials	Nonferrous Metals
New Cases	5.68E-08***	6.36E-08**	4.82E-08***	5.83E-08***	4.40E-08***	3.21E-08**	3.40E-08***	2.43E-08***
	(9.85E-09)	(9.94E-09)	(1.15E-08)	(7.62E-09)	(1.05E-08)	(1.25E-08)	(8.63E-09)	(7.60E-09)
New Deaths	3.30E-06***	2.33E-06***	4.49E-06***	1.87E-06***	2.08E-06***	5.06E-06***	1.93E-06***	4.05E-06***
	(4.69E-07)	(4.74E-07)	(5.48E-07)	(3.64E-07)	(5.02E-07)	(5.99E-07)	(4.12E-07)	(3.60E-07)
Total Cured	1.07E-09***	9.44E-09**	-7.07E-10	1.61E-09***	-1.15E-09***	1.93E-09***	3.49E-10	6.02E-10**
	(3.85E-10)	(3.91E-10)	(4.52E-10)	(2.99E-10)	(4.16E-10)	(5.03E-10)	(3.35E-10)	(2.97E-10)
Total Assets	0.00046***	0.00029***	0.00069***	0.00096***	0.00049***	0.00043***	0.00076***	0.00044***
	(9.52E-05)	(6.64E-05)	(7.00E-05)	(8.36E-05)	(7.84E-05)	(0.00010)	(6.09E-05)	(6.90E-05)
M/B Ratio	5.05E-05**	-4.48E-07	2.53E-05***	-0.00029***	-5.86E-05***	3.68E-06	-8.30E-05***	1.62E-05
	(2.07E-05)	(9.51E-06)	(5.63E-06)	(4.61E-05)	(1.72E-05)	(1.64E-05)	(8.13E-06)	(1.26E-05)
Turnover ratio	0.00874***	0.01667***	0.01217***	0.02065***	0.01332***	0.01358***	0.01146***	0.01350***
	(0.00031)	(0.00030)	(0.00033)	(0.00053)	(0.00029)	(0.00038)	(0.00027)	(0.00028)
Trading Volume	1.10E-11***	6.35E-12***	2.56E-12***	2.17E-12***	5.57E-12***	4.48E-12***	2.49E-12***	1.86E-12***
	(8.46E-13)	(7.10E-13)	(3.67E-13)	(3.16E-13)	(4.17E-13)	(5.79E-13)	(1.41E-13)	(1.91E-13)
– cons	-0.00691***	-0.0416***	-0.01054***	-0.01487***	-0.00692***	-0.00673***	-0.01271***	-0.00678***
	(0.00141)	(0.00099)	(0.00110)	(0.00129)	(0.00117)	(0.00156)	(0.00104)	(0.00107)

(*continued on next page*)

Table 4 (*continued*)

	Full sample	Agriculture	Banking	Chemicals	Commerce	Computer	Conglomerate	Construction Decoration
Obs.	28,180	73,629	32,076	13,608	38,394	15,066	16,038	25,515
	Real Estate	Tele-com	Textile & Apparel	Transportation	Utilities			
New Cases	4.11E-08***	2.98E-08**	7.59E-08***	5.81E-08***	7.05E-08***			
	(6.03E-09)	(1.43E-08)	(1.28E-08)	(8.80E-09)	(6.79E-09)			
New Deaths	2.32E-06***	6.40E-06***	3.82E-06***	2.82E-06***	3.64E-06***			
	(2.90E-07)	(6.85E-07)	(6.09E-07)	(4.22E-07)	(3.25E-07)			
Total Cured	2.34E-11	3.96E-09***	2.62E-10	5.38E-10	1.53E-09***			
	(2.35E-10)	(5.58E-10)	(4.99E-10)	(3.47E-10)	(2.64E-10)			
Total Assets	0.00030***	0.00126***	0.00069***	6.96E-05	0.00082***			
	(5.49E-05)	(0.00017)	(0.00015)	(8.58E-05)	(9.11E-05)			
M/B Ratio	5.98E-05***	-0.00018***	-0.00013**	0.00012***	-1.23E-05			
	(1.48E-05)	(2.62E-05)	(4.95E-05)	(1.98E-05)	(3.47E-05)			
Turnover ratio	0.01926***	0.01298***	0.01152***	0.0144	0.01488***			
	(0.00047)	(0.00040)	(0.00039)	(0.00045)	(0.00031)			
Trading Volume	5.84E-12***	3.51E-12***	5.87E-12***	7.14E-12***	2.13E-12***			
	(3.41E-13)	(5.81E-13)	(5.82E-13)	(4.43E-13)	(2.93E-13)			
– cons	-0.00461***	-0.01892***	-0.00974***	-0.00117***	-0.01276***			
	(0.00085)	(0.00256)	(0.00215)	(0.00134)	(0.00138)			
Obs.	26,730	21,141	18,225	25,515	33,291			

Notes. Numbers in parentheses are standard errors; Statistics is significant at *10%, **5% and ***1% level.

industry classification was terminated at the same time. In addition, the first wave of COVID-19 in China emerged in the first half of 2020 and the second wave emerged in the spring of 2022 which was identified as Omicron variant. In view of the above facts, we restricted the data for panel regression to the period between January 1, 2020 and December 31, 2020 to arrive at reasonably consistent long-run time series. Moreover, the data used at a daily frequency over the sample period are able to provide sufficient observations for our analysis.

The official data on *new cases and deaths* and *total cured* are sourced from the website of Wuhan Municipal Health Commission (WMHC) (January 1–January 10, 2020) and the NHC (January 11–December 31, 2020). The index and stock-related data are obtained from the China stock market and accounting research, Wind, and Choice databases. The index value and stock price are updated during weekdays, while the COVID-19 data are updated every day based on the data reported on the preceding day. We combine the COVID-19 variables with other variables by calendar dates. The full sample in the panel regression analysis comprises 795,096 observations.

4.2. Descriptive statistics of regression variables

Table 2 lists the descriptive statistics of regression variables for the full sample. The minimum and maximum values of stock return volatility indicate a wide swing. The maximum new cases and deaths and total cured are 14,109, 146 and 82,067, respectively, while the minimum number of cases is 0.

4.3. Descriptive analysis of pandemic and indices volatility

Figure 1 depicts the time trends of the cumulative confirmed, death, and cured COVID-19 cases in mainland China in 2020.

In 2020, mainland China reported 87,071 confirmed cases, including 82,067 recoveries and 4634 deaths. On December 27, 2019, several pneumonia cases of unknown cause were detected in Wuhan City, Hubei Province. After 3 days of epidemiological investigation, on December 31, 2019, the WMHC reported 27 confirmed cases to the WHO (WHO, 2020). On January 3, 2020, Wuhan City reported 44 cases; the first virus death was reported on January 11, 2020, following which the disease spread widely across China. As of January 30, the number of cumulative confirmed cases (local and imported) rose to 11,791, with 259 deaths and 243 recoveries. On February 12, an improvement to the diagnosis led to better detection and an exponential increase in confirmed cases, with the reported number surging to 15,152. To control the spread, the government implemented several epidemic prevention and control measures, including locking down cities, building specialized or temporary cabinet hospitals, and sending more than 42,000 voluntary medical staff from all over China to help Hubei. By early March, there was a consistent decline in new infections, indicating the effectiveness of the measures (Al-Awadhi et al., 2020). On March 18, for the first time, the city did not report new cases; on April 8, it lifted the 76-day lockdown, after no new deaths were reported for the first time. While occasional and small outbreaks were reported after the lockdown was lifted, these outbreaks were controlled through the timely implementation of social distancing, contact tracing, mass testing, and treatment measures; the number of deaths remained at 4634 during the May 16–December 31, 2020 period.

Following Eq. (1), we calculate the daily volatilities of sectoral indices before and during COVID-19, as shown in Figure 2. After January 2020, an intensification of the outbreak—an increase in the infections—led to a significant increase in the volatilities of all the sectoral indices, except for the nonbanking financials and food and beverage sectors. During the COVID-19 period, the reported volatility levels rivalled or exceeded those in the pre-COVID-19 period. In line with the sharp rise in confirmed cases, most indices peaked in mid-late February. The April–May period witnessed a downturn in the volatility level after cases levelled off in March. The outbreak in Beijing from June 10 to July 6 was accompanied by a small surge of volatility. In mid-late July, a rebound in locally transmitted cases in Xinjiang, Liaoning, and Beijing fueled a rising trend in volatility. After July, the sporadic local cases were controlled, which led to a decline in the volatility levels.

A notable difference in the volatility reactions across indices is observed. In the upper quartile, the volatility peaks for the leisure service, agriculture, computer, electronics, tele-com, media, construction materials, motor-dom, light-industry manufacturing, machinery equipment, nonferrous metals, and national defence industries. In the lower quartile, the volatility peaks for conglomerate, electrical equipment, utilities, and textile and apparel industries.

The descriptive analysis implies that the sectoral volatilities of the stock market are linked to the severity of the COVID-19 situation and there is an industry-wide variance in volatility reactions to COVID-19. Thus this study

Table 5. Results for robustness test.

	Full sample	Agriculture	Banking	Chemicals	Commerce	Computer	Conglomerate	Construction Decoration
New Cases	5.46E-08***	6.72E-08***	1.78E-08***	6.14E-08***	3.38E-08***	7.79E-08***	4.25E-08*	4.30E-08***
	(4.91E-09)	(1.60E-08)	(5.74E-09)	(8.84E-09)	(9.64E-09)	(1.32E-08)	(2.52E-08)	(9.71E-09)
New Deaths	2.31E-06***	5.47E-06***	2.00E-06***	2.89E-06***	4.13E-06***	7.92E-07	1.75E-06	2.39E-06***
	(2.67E-07)	(8.71E-07)	(3.12E-07)	(4.80E-07)	(5.24E-07)	(7.20E-07)	(1.37E-06)	(5.29E-07)
New Cured	-2.15E-09**	-7.85E-08***	-5.41E-08***	-3.73E-08**	-8.38E-08**	1.04E-07***	-2.69E-08	3.09E-09*
	(8.56E-09)	(2.79E-08)	(9.97E-09)	(1.54E-08)	(1.68E-08)	(2.32E-08)	(4.41E-08)	(1.72E-08)
Total Assets	0.00040***	4.50E-05	0.00056***	0.00029***	0.00043***	5.48E-05***	0.00012	0.00059***
	(2.82E-05)	(2.82E-05)	(0.00014)	(6.22E-05)	(7.05E-05)	(2.60E-05)	(0.00024)	(7.24E-05)
M/B Ratio	-2.15E-05***	2.55E-05***	-0.00035***	-3.12E-06	-6.25E-05***	1.38E-05***	-1.95E-05	1.94E-05
	(3.34E-06)	(4.89E-06)	(0.00013)	(0.00112)	(2.12E-05)	(4.00E-06)	(4.22E-05)	(1.25E-05)
Turnover ratio	0.0146***	0.0121***	0.00746***	0.0138***	0.0186***	0.01496***	0.0123***	0.0121***
	(0.00014)	(0.00046)	(0.00023)	(0.00022)	(0.00049)	(0.00032)	(0.00067)	(0.00030)
Trading Volume	3.88E-08***	2.28E-08***	1.92E-08***	4.76E-08***	4.63E-08***	3.30E-08***	2.72E-08***	6.99E-08***
	(1.62E-09)	(5.72E-09)	(8.80E-10)	(3.35E-09)	(3.80E-09)	(5.75E-09)	(8.87E-09)	(3.36E-09)
– cons	-0.00595***	-0.00044	-0.01000***	-0.00409***	-0.00623***	-0.00056	-0.00139	-0.00903***
	(0.00044)	(0.00044)	(0.00244)	(0.00094)	(0.0005)	(0.00040)	(0.00349)	(0.00110)
Obs.	795,096	17,496	8505	71,199	18,225	53,031	6318	25,272
	Construction Materials	Electrical Equipment	Electronics	Food & Beverage	Health Care & Pharmaceutical Products	Household Appliances	Iron & Steel	Leisure Service
New Cases	3.85E-08**	3.01E-08	1.03E-07***	5.12E-08***	7.76E-08***	6.32E-08**	2.94E-08	1.73E-08
	(1.61E-08)	(6.77E-08)	(1.18E-08)	(1.66E-08)	(9.06E-09)	(1.77E-08)	(2.64E-08)	(2.32E-08)
New Deaths	3.61E-06***	1.97E-06	-2.73E-06***	1.87E-06***	3.98E-06***	2.14E-06***	3.00E-06**	4.58E-06***
	(8.73E-07)	(3.68E-06)	(6.41E-07)	(9.04E-07)	(4.92E-07)	(9.63E-07)	(1.43E-06)	(1.26E-06)
New Cured	-7.46E-08**	*1.40E-07*	1.44E-07***	-1.71E-08	-1.23E-07***	-5.81E-09	-7.82E-08*	-7.07E-08*
	(2.81E-08)	(1.18E-07)	(2.06E-08)	(2.94E-08)	(1.58E-08)	(3.12E-08)	(4.59E-08)	(4.03E-08)
Total Assets	1.02E-05	0.0027***	0.00013*	0.00099***	0.00049***	0.00073***	0.00049	8.18E-05**
	(3.51E-05)	(0.00043)	(7.57E-05)	(9.60E-05)	(5.33E-05)	(0.00015)	(0.00031)	(3.24E-05)
M/B Ratio	4.04E-05***	-0.00077***	-1.15E-06	-6.54E-05***	2.62E-06	4.09E-05	-0.00017	2.17E-07
	(8.84E-06)	(6.63E-05)	(7.90E-06)	(9.17E-06)	(5.44E-06)	(3.28E-05)	(0.00013)	(8.96E-07)
Turnover ratio	0.0167***	0.0185***	0.0139***	0.0104***	0.0137***	0.0153***	0.0156***	0.0081***
	(0.00070)	(0.00176)	(0.00026)	(0.00059)	(0.00026)	(0.00068)	(0.00168)	(0.00157)
Trading Volume	7.35E-08***	1.24E-07***	1.51E-08***	1.20E-17***	7.35E-08***	6.08E-08***	1.69E-08***	3.04E-07***
	(1.06E-08)	(2.06E-08)	(2.53E-09)	(1.33E-08)	(5.21E-09)	(7.41E-09)	(4.57E-09)	(3.40E-08)
– cons	2.66E-05	-0.0387***	-0.00166	-0.0154***	-0.00753***	-0.0108***	-0.00749	-0.00098**
	(0.00054)	(0.0066)	(0.00118)	(0.00153)	(0.00083)	(0.0023)	0.00488	(0.00049)
Obs.	15,552	40,338	55,647	20,898	70,956	12,879	7533	7776
	Light-industry Manufacturing	Machinery Equipment	Media	Mining	Motor-dom	National Defense	Nonbanking Financials	Nonferrous Metals
New Cases	4.03E-08***	4.19E-08***	4.80E-08***	2.20E-08	5.74E-08***	3.63E-08	4.77E-08***	3.79E-08**
	(1.14E-08)	(1.48E-08)	(1.32E-08)	(1.32E-07)	(1.20E-08)	(2.32E-08)	(9.69E-09)	(1.72E-08)
New Deaths	3.46E-06***	3.16E-06***	4.57E-06***	2.82E-06	1.08E-06***	2.46E-06*	7.33E-08	1.43E-06
	(6.16E-07)	(8.01E-07)	(7.18E-07)	(7.15E-06)	(6.51E-07)	(1.26E-06)	(5.26E-07)	(9.33E-07)
New Cured	-5.45E-08**	-7.8E-08**	-2.0E-08	-1.66E-07	5.20E-08***	4.73E-08	6.37E-08***	6.29E-08**
	(1.98E-08)	(2.57E-08)	(2.29E-08)	(2.28E-07)	(2.08E-08)	(4.05E-08)	(1.69E-08)	(2.99E-08)
Total Assets	0.00037***	0.00030***	0.00058	-3.31E-05	0.00039***	0.00057***	0.00072***	5.79E-05*
	(9.98E-05)	(8.93E-05)	(0.00073)	(0.0001)	(8.05E-05)	(0.00017)	(6.29E-05)	(3.31E-05)
M/B Ratio	5.90E-05**	-3.90E-06	2.62E-05***	-6.99E-05***	-4.86E-05***	-5.1E-05*	-7.81E-05***	5.59E-05***
	(2.17E-05)	(1.28E-05)	(5.85E-06)	(8.93E-05)	(1.78E-05)	(2.77E-05)	(8.39E-06)	(1.00E-05)
Turnover ratio	0.0089***	0.0151***	0.01273***	0.0240***	0.0136***	0.0140***	0.0115***	0.0146***
	(0.00032)	(0.00041)	(0.00035)	(0.00641)	(0.00030)	(0.00064)	(0.00028)	(0.00054)
Trading Volume	1.21E-07***	9.37E-08***	2.69E-08***	2.17E-08	5.63E-08***	4.49E-08***	2.42E-08***	1.90E-08***
	(8.88E-09)	(9.72E-09)	(3.84E-09)	(3.85E-08)	(4.31E-09)	(9.79E-09)	(1.45E-09)	(3.60E-09)
– cons	-0.00556***	-0.00423***	-0.0089***	0.00092	-0.00553***	-0.0087***	-0.0119***	-0.00078***
	(0.00148)	(0.00133)	(0.0011)	(0.00160)	(0.00120)	(0.0026)	(0.00108)	(0.00052)
Obs.	28,180	73,629	32,076	13,608	38,394	15,066	16,038	25,515

(*continued on next page*)

Table 5 (*continued*)

	Full sample	Agriculture	Banking	Chemicals	Commerce	Computer	Conglomerate	Construction Decoration
	Real Estate	Tele-com	Textile & Apparel	Transportation	Utilities			
New Cases	4.07E-08***	5.49E-08**	5.44E-08***	2.47E-08***	4.93E-08***			
	(6.86E-09)	(1.64E-08)	(1.46E-08)	(1.01E-08)	(7.80E-09)			
New Deaths	1.97E-06***	-2.58E-08	5.49E-09	4.76E-06***	4.67E-06***			
	(3.72E-07)	(8.94E-07)	(7.93E-07)	(5.48E-07)	(4.23E-07)			
New Cured	-3.30E-09	2.02E-07***	-1.18E-07***	-1.14E-07***	-1.17E-07***			
	(1.20E-08)	(2.98E-08)	(2.56E-08)	(1.75E-08)	(1.36E-08)			
Total Assets	0.00023***	0.00085***	0.00068***	-3.56E-05**	0.00067***			
	(5.69E-05)	(0.00018)	(0.00015)	(1.77E-05)	(9.52E-05)			
M/B Ratio	5.78E-05***	-0.00013***	-0.00015**	0.00010***	-7.75E-06			
	(1.53E-05)	(2.72E-05)	(5.12E-05)	(1.00E-05)	(3.62E-05)			
Turnover ratio	0.0197***	0.0127***	0.0120***	0.0153	0.0157***			
	(0.00049)	(0.00048)	(0.00049)	(0.00046)	(0.00032)			
Trading Volume	6.25E-08***	3.23E-08***	5.77E-08***	7.14E-08***	2.57E-08***			
	(3.35E-09)	(6.12E-09)	(6.06E-09)	(4.34E-09)	(3.05E-09)			
− *cons*	-0.00345***	-0.0125***	-0.00953***	0.00056***	-0.0102***			
	(0.00088)	(0.00268)	(0.00222)	(0.00028)	(0.00144)			
Obs.	26,730	21,141	18,225	25,515	33,291			

Notes. Numbers in parentheses are standard errors; Statistics is significant at *10%, **5% and ***1% level.

proposes the hypothesis that COVID-19 pandemic has positive impact on stock market volatility and the impact varies by industry.

5. Results and discussion

5.1. Results of the event study and univariate graphic analysis and discussion

Bases on Eq. (2), we calculate the movements of 28 sectoral indices' return volatility before and after the COVID-19-related event. Figure 3 contains 28 panels and each of those small graphs portrays the behaviour of the index's volatility of a specific industry for a 16-day window around the outbreak of the COVID-19-related event, beginning 8 trading days before the event, continuing through the event (marked by a vertical bar) and ending 8 trading days after the event. The estimated coefficient $\beta_{js}(s \in [-8, 8])$ is reported on the vertical axis and plotted as a solid line over the event window, along with dotted lines denoting 95% confidence intervals equal to plus/minus two standard deviations. The horizontal axis displays the time component that records the number of days before (negative sign) and after the day that marks the beginning of the event (s = 0 in event time), which is indicated by a vertical dashed line.

We observe that the COVID-19 events impact volatility across all sectors, and the magnitudes of the COVID-19 impact vary widely across different industries—the episode is more significant for some (Rizvi et al., 2022). The leisure service industry has the biggest post-event peak value of coefficient (0.05082), followed by electronics (0.03205), national defence (0.02631), electrical equipment (0.02490), agriculture (0.02385) and motor-dom (0.02274), suggesting that these industries fluctuate strongly in response to COVID-19 events. As one of the most vulnerable industries to crises and disasters, the leisure service industry including restaurants, hotels, entertainments etc., has experienced the hardest hit of COVID-19 and is among the most adversely affected industries worldwide (Abbas et al., 2021). This is understandable because COVID-19 is primarily transmitted through direct or indirect person contact, people are highly encouraged to maintain social distancing and avoid unnecessary interactions to prevent or slow down infection transmission, leading to unprecedented disruptions to the leisure service sector which is more conducive to virus transmission and therefore more heavily affected by the imposition of social distancing (Alfaro et al., 2020). The COVID-19 exerts relatively more influence on the electronics, national defence, electrical equipment and motor-dom industries because they face an increasingly constrained supply chain due to strict pandemic control and prevention measures, such as complete and partial lockdown, which reduce potential output and demand from other sectors. In addition, the agricultural sector tends to suffer more from the pandemic's impact on procurement and logistics, as well as the impact on the supply or access to essential farm inputs. By contrast, banking, real estate and utilities respectively reach their post-event coefficient peaks at 0.00488, 0.00538 and 0.00659, which are much smaller than those for other sectors. The less impact on the banking sector may stem from its excellent quality of balance sheet and solvency levels, and its ability to conduct business online (Alfaro et al., 2020). A possible explanation for the less pressure on the real estate sector might be that it has generated steady cash flow and returns significantly above those of many sectors over the last decade, which have placed it in a better position to absorb the crisis generated by the pandemic. In addition, policy measures adopted to stabilize housing prices and market expectations have helped to mitigate the impact of COVID-19. The utilities sector is a less volatile sector compared to others, likely due to its necessity or its ability to continue operation on line (Alfaro et al., 2020). The post-event peak values of coefficients of other industries in descending order are nonferrous metals, tele-com, household appliance, media, construction materials, computer, health care and pharmaceutical products, light-industry manufacturing, machinery equipment, chemicals, commerce, nonbanking financials, textile and apparel, construction decoration, mining, food and beverage, as well as iron and steel, ranging from 0.01917 to 0.00896.

It also should be noted that the indices' return volatilities of banking, banking, non-banking financials, real estate and construction decoration are on a downward trend as shown in Figure 3, i.e., the indices' return volatilities of these industries are lower in the *post-event* phase than that in the *pre-event* phase—the volatilities of these sectors are also relatively lower than that of most sectors. One behavioural and psychological explanation for this result is that when facing financial shocks, investors may be more pessimistic about these industries which by their nature are usually more vulnerable in times of macroeconomic and financial instabilities (Goodell, 2020). This may result in the behaviour about what we refer to as "ostrich effect" (Galai and Sade, 2006): the investors may prefer to simply "put their head in the sand" rather than trade. The decreases in trading activities will depress stock return volatility.

Moreover, the COVID-19-related events increased market volatility continuously for up to 6 days. We note that mining hits the biggest value

of coefficient on Day 0, leisure service, nonferrous metals, household appliance, and iron and steel climb to their peaks on Day 1, electronics, national defence, electrical equipment, motor-dom, computer, health care and pharmaceutical products, light-industry manufacturing, food and beverage find their peaks on Day 2, and other industries reach their highest levels on Day 5, indicating that some sectors may have had prior knowledge or understanding of the pandemic's risk and there were immediate market reactions in these sectors, while some sectors were slow to react to the events. For example, the rapid response of the mining sector is not surprising given the implications of the sharp contraction in economic activity on energy demand and the consequent price shocks (Baek et al., 2020; Alfaro et al., 2020).

5.2. Results of panel regression and discussion

First, the Fisher test for panel unit root using an augmented Dickey-Fuller (ADF) test is employed. The results (Table 3) indicate that all the variables are stationary at the level and integrate of order zero. This suggests that the panel data can be used for the regressions, with no need to test the co-integration relationship among the time series variables.

The results of the Hausman test suggest that random-effects regression is appropriate for the leisure service, agriculture, computer, construction materials and conglomerate industries, while fixed-effects regression is appropriate for the full sample and 23 other industries. Following Eqs. (1) and (3), we run the panel regression on the full sample and subsequently repeat it on 28 sectors separately. Table 4 displays the regression results.

The results for the full sample show that the COVID-19-related daily new cases and deaths and cumulative cured cases significantly increase the stock return volatility. However, the effects are small, as the parameter estimates of *new cases and deaths* and *total cured* indicate. This result was also reported by Kusumahadi and Permana (2021) who examined the impact of COVID-19 on stock volatility in 15 countries using threshold generalized autoregressive conditional heteroscedasticity regressions. Our results reveal that the impact of the new deaths is stronger than those of the new confirmed and total cured cases. The findings with respect to new cases and new deaths support evidence from previous observations (e.g. Ali et al., 2020; Baek et al., 2020; Onali, 2020; Albulescu, 2021; Baek and Lee, 2021; Baig et al., 2021; Sergi et al., 2021). However, in contrast to earlier results obtained by Baek et al. (2020) and Baek and Lee (2021) that the growth rate of recoveries decreased volatility, the coefficient of the cumulative cured cases in our study bears a positive sign. A possible explanation for this finding is that the cumulative cured cases represent the direct outcome of confirmed cases, and the market reacts to them in the lagged impact of infection confirmation (Ashraf, 2020).

The tests for each of the 28 industries show that the coefficients on the new cases and deaths are significantly positive for all industries, except for the iron and steel industry, which reacts insignificantly. The number of total cured cases exerts significantly positive impacts on 17 industries. The qualitatively similar results as those obtained for the full sample further support the overall positive effect of COVID-19 shocks.

Sector-wise, different industries are affected by new cases, new deaths, and total cured cases to varying degrees. With respect to daily new cases, the health care and pharmaceutical products industry is the most severely affected—on average, every one percent increase in the number of daily new cases is associated with 0.0000000949 percent increase in the stock return volatility. This is followed by textile and apparel, agriculture and utilities which respectively show estimated coefficients of 0.0000000759, 0.0000000719 and 0.0000000705. Slight effects are reported in nonferrous metals, banking and tele-com sectors—daily new cases rise of every one percent will increase stock return volatility of nonferrous metals, banking and tele-com sectors by 0.0000000243 percent, 0.0000000250 percent and 0.0000000298 percent respectively. Concerning the daily new deaths, tele-com dominates its peers with the biggest magnitude of coefficient (0.0000064). This is followed by computer (0.00000539), agriculture (0.00000510) and national defense (0.00000506). In comparison with other industries, stock return volatility is less affected by new deaths in banking, ming and nonbanking financials, which respectively show estimated coefficients of 0.00000166, 0.00000187 and 0.00000193. We find no evidence that daily new cases and new deaths affect stock return volatility of iron and steel industry, and this result differs from those for the other industries in our sample. The number of cumulative cured cases is positively associated with volatilities in 17 industrial sectors. Specifically, the association is strong for machinery equipment and weak for non-ferrous metals, commerce and banking. Moreover, the effect is positive but not statistically significant for 8 sectors. By contrast, the signs of the coefficients turn out to be significantly negative for motor-dom and iron and steel industries, and negative without statistical significance for media.

Surprisingly, banking is relatively less affected. A possible explanation for this might be that the government's lenient monetary policy response has provided adequate liquidity, thereby stabilizing the market and easing the volatility of the banking industry (Heyden and Heyden, 2021). This result is also likely related to the fact that the banking sector is less sensitive due to greater ability to continue operation on line (Alfaro et al., 2020).

We also record positive significant effects of total assets. During a crisis, high asset firms tend to sell assets to raise cash, particularly when they are in financial distress (Pulvino, 1998), which may trigger more volatility. The positive significant effects of turnover ratio and trading volume are in line with our expectations. Nonetheless, the M/B ratio receives mixed results. A possible reason is that the long-run time-varying characteristics, such as the M/B ratio, across years cannot be incorporated because of the relatively short sample period (Chan and Kwok, 2018). Notably, the results show that total assets, turnover ratio and trading volume are also important drivers of volatility in pandemic period, and in-depth studies of other factors that may affect stock return volatility besides the occurrence of COVID-19 needs to be conducted (Kusumahadi and Permana, 2021).

5.3. Robustness test

We perform robustness test to further confirm the above main panel regression results. We re-estimate Eq. (3) by using the number of new recovered cases (*New Cured*) instead of cumulative recovered cases (*Total Cured*). As shown in Table 5, *New Cured* presents negative and significant effects on full sample and 14 sectors. This result is in line with the findings of Baek et al. (2020) and Baek and Lee (2021). The finding also reveals that the number of cumulative recovered cases seems to have different behavioural and psychological effect on investors from that of new recovered cases. In addition, we observe that other results are quite similar to those reported in Table 4, confirming that our main results are robust.

6. Conclusion

Based on data up to December 31, 2020, this paper examined the impact of COVID-19 on China's stock market volatility. The descriptive analysis of the index return volatility showed that the index return of each industry exhibits high volatility during the COVID-19 pandemic. To capture the short- and long-term associations between COVID-19 and volatility, we employed event study and univariate graphic analysis and panel regression approach, respectively. The results of the event study and univariate graphic analysis showed that the market volatilities of the 28 industries were affected by sudden COVID-19 events at varying levels and that the events increased the volatility continuously for up to 6 days. The results of the panel regression models revealed that overall, the COVID-19-related daily new cases, daily new deaths, and cumulative cured cases were associated with higher volatility for all industries, and the levels of impact varied across different sectors. The volatility is highly related to market uncertainty and therefore strongly affects investors'

investment decisions. As one of the most significant Black Swan events (Zaremba et al., 2021), the global outbreak of COVID-19 has triggered unprecedented crises in financial markets and beyond, and therefore significantly fueled sentiment and uncertainty among investors, and eventually elevated stock volatility. One implication of the findings is that portfolio diversification should be considered in the context of pandemics given the heterogeneous reactions of different industries.

The COVID-19 pandemic was not the only source of stock market volatility. Positive and significant effects of firm-specific variables of total assets, turnover ratio and trading volume were well documented, indicating that fundamental aspects of the company and investors' behaviour also made great sense. There are possibly some other important influential factors or contemporaneous events that we did not address in the current study. Future studies may discuss the influences of global financial markets, government policy responses, vaccine inoculation, and other macro or micro factors. Although the COVID-19 pandemic remains a threat in many countries across the world since there is no end in sight, efforts to contain the spread of the disease and to scale up vaccination fueled hopes for future global economic recovery and rebound, and the positive sentiment may boost stock market performance.

Declarations

Author contribution statement

Wei Zhang: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Wenqian Hou: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Chunhui Qu: Performed the experiments.

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Data will be made available on request.

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